Soutenance de thèse de doctorat

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Lundi 07/10/2019, 15:30-18:00

Orme des Merisiers Amphi Claude Bloch, Bât. 774

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IPhT

Out-of-equilibrium transport in the interacting resonant level model

The fields of in- and out-of-equilibrium quantum many-body systems are major topics in Physics, and in condensed-matter Physics in particular. The equilibrium properties of one-dimensional problems are well studied and understood theoretically for a vast amount of interacting models, from lattice spin chains to quantum fields in a continuum. These progresses were allowed by the development diverse powerful techniques, for instance, Bethe ansatz, renormalization group, bosonization, matrix product states and conformal field theory. Although the equilibrium characteristics of many models are known, this is in general not enough to describe their non-equilibrium behaviors, the latter often remain less explored and much less understood. Quantum impurity models represent some of the simplest many-body problems. But despite their apparent simplicity, they can capture several important experimental phenomena, from the Kondo effect in metals to transport in nanostructures such as point contacts or quantum dots.

In this thesis consider a classic impurity model - the interacting resonant level model (IRLM). The model describes spinless fermions in two semi-infinite leads that are coupled to a resonant level – called quantum dot or impurity – via weak tunneling and Coulomb repulsion. We are interested in out-of-equilibrium situations where some particle current flows trough the dot, and study transport characteristics like steady current (versus voltage), differential conductance, backscattered current, current noise or the entanglement entropy. We perform extensive state-of-the-art computer simulations of model dynamics with the time-dependent density renormalization group method (tDMRG) which is based on a matrix product state description of the wave functions. We obtain highly accurate results concerning the current-voltage and noise-voltage curves of the IRLM in a wide range parameter of the model (voltage bias, interaction strength, tunneling amplitude to the dot, etc.). These numerical results are analyzed in the light of some exact out-of-equilibrium field-theory results that have been obtained for a model similar to the IRLM, the boundary sine-Gordon model (BSG). This analysis is in particular based on identifying an emerging Kondo energy scale and relevant exponents describing the high- and low- voltage regimes. At the two specific points where the models are known to be equivalent our results agree perfectly with the exact solution. Away from these two points we find that, within the precision of our simulations, the transport curves of the IRLM and BSG remain very similar, which was not expected and which remains somewhat unexplained.
